

CLAIMS

I/We claim:

- [c1] 1. Apparatus for interrogating a sample that exhibits low-frequency molecular motion, comprising
- a container adapted for receiving said sample, said container having both magnetic and electromagnetic shielding,
 - an adjustable-power source of Gaussian noise for injection into the sample, with the sample in said container,
 - a detector for detecting an electromagnetic time-domain signal composed of sample source radiation superimposed on the injected Gaussian noise, and
 - an electronic computer adapted to receive the time-domain signal from the detector, and to process the signal to generate a spectral plot that displays, at a selected power setting of the Gaussian noise source, low-frequency spectral components characteristic of the sample in a selected frequency range between DC and 50 kHz.
- [c2] 2. The apparatus of claim 1, wherein said electronic computer includes a signal analyzer that functions to (i) calculate a series of Fourier spectra of the time-domain signal over each of a plurality of defined time periods, in a selected frequency range between 100 and 50 kHz, and (ii) average the Fourier spectra.
- [c3] 3. The apparatus of claim 2, wherein said calculating includes calculating at least five Fourier spectra, each taken over a 1-5 second time-domain interval.
- [c4] 4. The apparatus of claim 1, wherein said electronic computer includes machine readable code operable to:
- (i) store a time-domain signal of the sample over a sample-duration time T;

- (ii) select a sampling rate F for sampling the time domain signal, where $F \cdot T$ is the total sample count S , F is approximately twice the frequency domain resolution f of a Real Fast Fourier Transform of the time-domain signal sampled at sampling rate F , and $S > f \cdot n$, where n is at least 10,
- (iii) select S/n samples from the stored time domain signal and performing a Real Fast Fourier Transform (RFFT) on the samples,
- (iv) normalize the RFFT signal and calculating an average power for the signal,
- (v) place an event count in each of f selected-frequency event bins where the measured power at the corresponding selected frequency $>$ average power $\cdot \epsilon$ obtains, where $0 < \epsilon < 1$, and is chosen such that the total number of counts placed in an event bin is between about 20-50% of the maximum possible bin counts in that bin,
- (vi) repeat steps (iii-v) times, and
- (viii) generate a histogram that shows, for each event bin f over a selected frequency range, the number of event counts in each bin.

[c5] 5. The apparatus of claim 4, wherein said machine readable code is further operable to, in step (iv) place the normalized power value from the RFFT in f corresponding-frequency power bins, and in step (viii) (a) divide the accumulated values placed in each of the f power bins by n , to yield an average power in each bin, and (b) display on the histogram, the average power in each bin.

[c6] 6. The apparatus of claim 4, wherein said machine readable code is further operable to, in step (viii), identify those bins in the histogram that have an event count above a given threshold and a average power.

[c7] 7. The apparatus of claim 1, wherein the source of Gaussian noise includes an adjustable-power Gaussian noise generator and a Helmholtz coil which

is contained within the magnetic cage and the Faraday cage, and which receives a selected noise output signal from the noise generator in the range 100 mV to 1 V.

[c8] 8. The apparatus of claim 7, wherein said injector is designed to inject Gaussian noise into the sample at a frequency between DC and 2 kHz.

[c9] 9. The apparatus of claim 1, wherein said detector is a first-derivative superconducting gradiometer which outputs a current signal, and a SQUID operatively connected to the gradiometer to convert the current signal to an amplified voltage signal.

[c10] 10. The apparatus of claim 9, wherein said container is an attenuation tube having a sample-holding region, a magnetic shielding cage surrounding said region, and a Faraday cage contained within the magnetic shielding cage and also surrounding said region, the source of Gaussian noise includes a Gaussian noise generator and a Helmholtz coil which is contained within the magnetic cage and the Faraday cage, and which receives a noise output signal from the noise generator, and which further includes, for use in removing stationary noise components in the time-dependent signal, a signal inverter operatively connected to the said noise source and to said SQUID, for receiving Gaussian noise from the noise source and outputting into said SQUID, Gaussian noise in inverted form with respect to the Gaussian noise injected into the sample.

[c11] 11. A method for interrogating a sample that exhibits low-frequency molecular motion, comprising
placing the sample in a container having both magnetic and electromagnetic shielding,
(a) injecting Gaussian noise into the sample at a selected noise amplitude;

- (b) recording an electromagnetic time-domain signal composed of sample source radiation superimposed on the injected Gaussian noise,
- (c) generating a spectral plot that contains, at a selected power setting of the Gaussian noise source, low-frequency, sample-dependent spectral components characteristic of the sample in a selected frequency range between 100 and 50 kHz, and
- (d) repeating steps (a)-(c) at different selected noise amplitudes until a plot showing a maximum or near maximum number of spectral components characteristic of the sample are generated.

[c12] 12. The method of claim 11, wherein said generating includes (i) calculating a series of Fourier spectra of the time-domain signal over each of a plurality of defined time periods, in a selected frequency range between 100 and 50 kHz, and (ii) averaging the Fourier spectra.

[c13] 13. The method of claim 11, wherein said calculating includes

- (i) storing a time-domain signal of the sample over a sample-duration time T ;
- (ii) selecting a sampling rate F for sampling the time domain signal, where $F * T$ is the total sample count S , F is approximately twice the frequency domain resolution f of a Real Fast Fourier Transform of the time-domain signal sampled at sampling rate F , and $S > f * n$, where n is at least 10,
- (iii) selecting S/n samples from the stored time domain signal and performing a Real Fast Fourier Transform (RFFT) on the samples,
- (iv) normalizing the RFFT signal and calculating an average power for the signal,
- (v) placing an event count in each of f selected-frequency event bins where the measured power at the corresponding selected frequency $>$

average power * ϵ obtains, where $0 < \epsilon < 1$, and is chosen such that the total number of counts placed in an event bin is between about 20-50% of the maximum possible bin counts in that bin,

(vi) repeating steps (iii-v) times, and

(viii) generating a histogram that shows, for each event bin f over a selected frequency range, the number of event counts in each bin.

[c14] 14. The method of claim 13, which further includes, in step (iv) placing the normalized power value from the RFFT in f corresponding-frequency power bins, and in step (viii) (a) dividing the accumulated values placed in each of the f power bins by n , to yield an average power in each bin, and (b) displaying on the histogram, the average power in each bin.

[c15] 15. The method of claim 14, which further includes, in step (viii). identifying those bins in the histogram that have an event count above a given threshold and a average power.

[c16] 16. A method of characterizing spectral emission features of a sample material, over a selected frequency range R , comprising

- (i) storing a time-domain signal of the sample over a sample-duration time T ;
- (ii) selecting a sampling rate F for sampling the time domain signal, where $F * T$ is the total sample count S , F is approximately twice the frequency domain resolution f of a Real Fast Fourier Transform of the time-domain signal sampled at sampling rate F , and $S > f * n$, where n is at least 10,
- (iii) selecting S/n samples from the stored time domain signal and performing a Real Fast Fourier Transform (RFFT) on the samples,
- (iv) normalizing the RFFT signal and calculating an average power for the signal,

- (v) placing an event count in each of f selected-frequency event bins where the measured power at the corresponding selected frequency $>$ average power $\times \epsilon$ obtains, where $0 < \epsilon < 1$, and is chosen such that the total number of counts placed in an event bin is between about 20-50% of the maximum possible bin counts in that bin,
- (vi) repeating steps (iii-v) times, and
- (viii) generating a histogram that shows, for each event bin f over a selected frequency range, the number of event counts in each bin.

[c17] 17. The method of claim 16, which further includes, in step (iv) placing the normalized power value from the RFFT in f corresponding-frequency power bins, and in step (viii) (a) dividing the accumulated values placed in each of the f power bins by n , to yield an average power in each bin, and (b) displaying on the histogram, the average power in each bin.

[c18] 18. The method of claim 17, which further includes, in step (viii), identifying those bins in the histogram that have an event count above a given threshold and an average power.

[c19] 19. The method of claim 18, wherein R , expressed in Hz, is approximately equal to f , and the sample rate F , expressed in samples/second, is approximately $2f$.

[c20] 20. The method of claim 19, wherein the method detects low-frequency emission events related to molecular in a sample, and wherein R includes at least the frequency range 1-5 kHz.

[c21] 21. A low-frequency spectral signature associated with a material of interest comprising
a list of frequency components in the DC-50 kHz frequency range that are generated by the method of claim 16.

[c22] 22. The spectral signature of claim 21, wherein the frequencies in said list are identified from a histogram of the number of sample-dependent stochastic events occurring at each of a plurality of spectral increments within a selected frequency range between DC and 50 kHz.